Chapter #4

Engine Introduction

- Design/Classification
- Moving Engine Parts
- Four Stroke Cycle
- Valve Timing
- Measurements & Performance

MidnightSpecial Enterprises

Chapter 4:
Engine Introduction

Engine Design and Classification

Piston type engines are divided into categories in a number of ways according to different mechanical or operational features. Keep in mind that not all engines are used in cars and trucks. Each engine is designed with a set of operational features in mind: some are very specialized and some are commonplace.

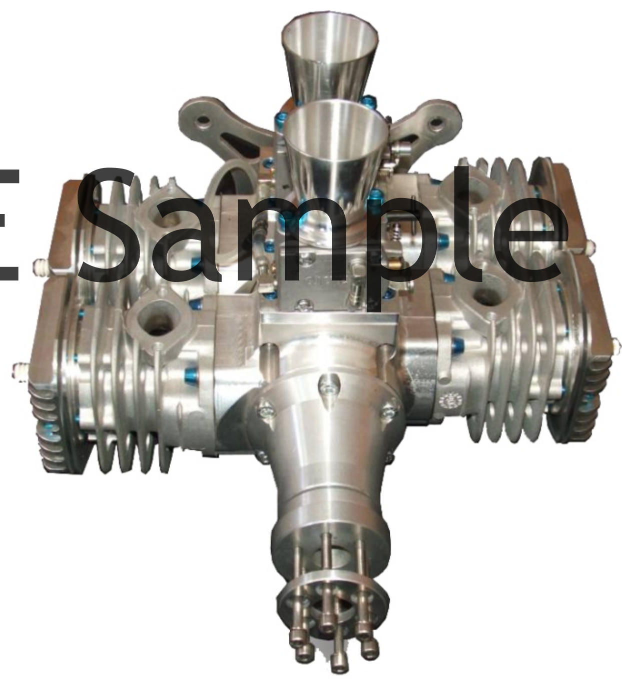
A. 6 Cylinder Inline Engine

The 6 cylinder inline engine is used in some pick-up trucks and mid-sized cars. Mercedes and Audi use a 5 cylinder inline engine in some models. Some diesel trucks are equipped with a large 6 cylinder Detroit Diesel inline engine.

6 Cylinder Inline Engine

B. Horizontally Opposed Engine

The horizontally opposed 4 cylinder was a very popular engine installed in the Volkswagen Beetle. Porsche still uses this type of engine. The horizontally opposed engine is often installed in light aircraft and this, like many other opposed engines, is air cooled. The opposed engine is lightweight and compact with reasonable output. Other names for the horizontally opposed engine are pancake engine, boxer engine and flat engine.



Horizontally Opposed Engine

C. V-8 Engine

The V-8 is a popular engine when high horsepower output is required. The V8 is often installed in performance vehicles, full sized cars and trucks. Some cars are equipped with other types of V engines with a larger number of cylinders. ie Chrysler's V-10 engine and Jaguar's V-12.

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- Engine Classification
- 6 Cylinder Inline Engine
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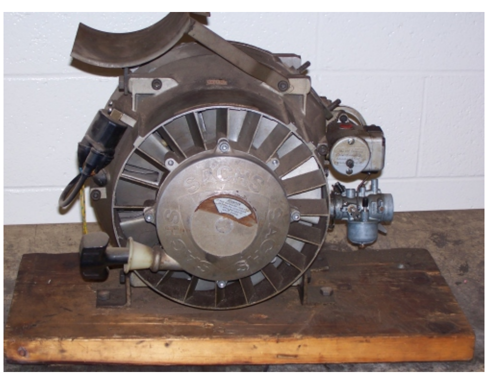
- V-8 Engine

V8 Engine

D. Rotary Engine

The rotary engine is unique in that its cylinders are built into a spinning rotor. Another name for the rotary engine is the Wankel engine, after its inventor Felix Wankel. Mazda has built millions of RX model cars equipped with a rotary engine and had **fair success** with it. This engine is fairly compact, has few moving parts and provides considerable output.



Rotary Engine

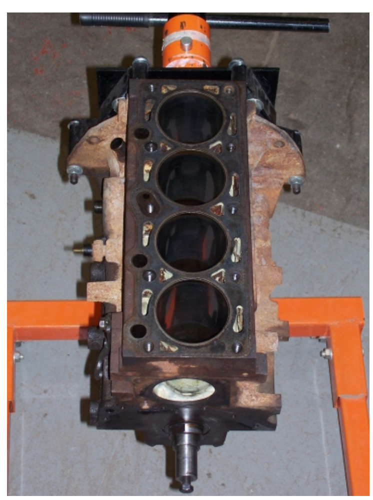
E. V-6 Engine

The V-6 is a very popular engine configuration. This engine is compact and easily adapted to fit into many models of vehicles. Some V6 engines are capable of fairly high horsepower output. They may be mounted **transversely** or **front to back** . Many diesel buses and some trucks are equipped with a large V6 Detroit Diesel engine.

V-6 Engine

F. 4 Cylinder Inline Engine

The 4 cylinder inline engine is commonly used in compact cars. This engine is fairly small and can easily be installed transversely or front to back . Some compact cars are equipped with a 3 cylinder inline engine.



4 Cylinder Inline Engine

Know the Language

fair success

When Mazda installed the rotary engine in its RX car models it was slow in getting positive consumer response. The engine had a problem with an important seal (apex seal) which was corrected. Consumers are typically slow to purchase a vehicle with such a radically new type of engine. Good marketing ideas and a winning racing program eventually proved that the rotary engine is a good engine.

transversely

In a direction from side to side. In this case it refers to the engine being mounted sideways instead of front to back. Transverse engine installation is used in most front wheel drive vehicles and many city transit buses.

front to back

In a direction following a line from front to back. In this case it refers to the engine being mounted in a front to back direction. This type of installation is used in most rear wheel drive vehicles.

Valve Arrangement

Valve arrangement has to do with the location of the valves relative to the cylinder they service. See **Diagrams 4.2** to view the four valve arrangements in use today.

L head is used in some stationary engines, older marine engines and is very popular in small engines. It is not a very efficient design with regards to easy airflow through the cylinder but it is very simple and provides years of trouble-free service.

I head is the most common arrangement used today. It is very efficient as far as airflow through the cylinder goes and is very reliable. Newer engines have reduced the number of parts in the valve operating system by using an overhead camshaft.

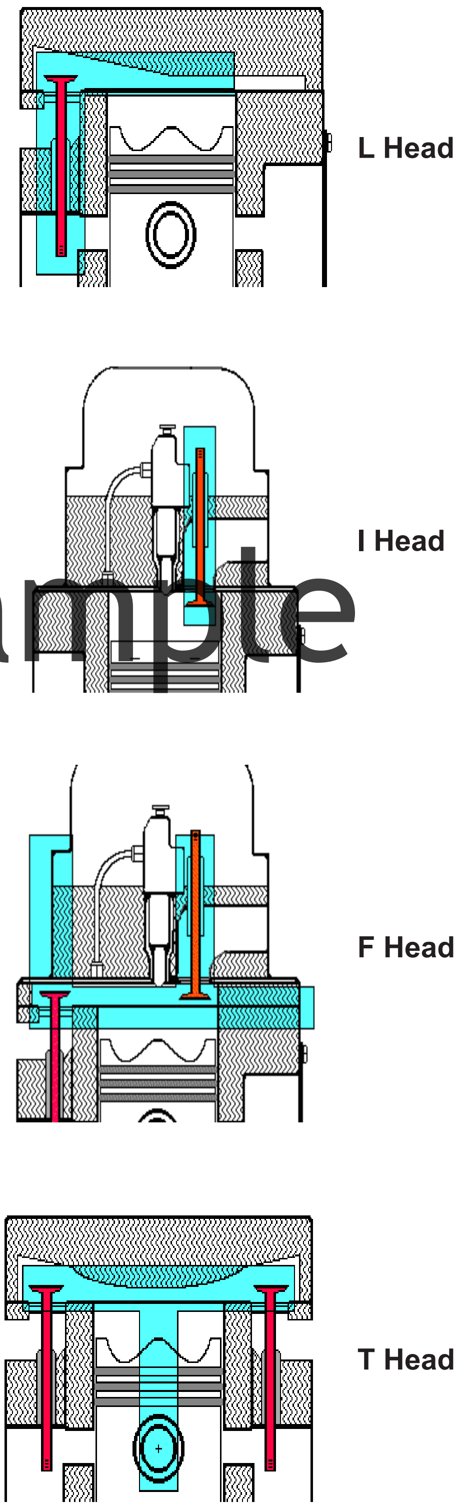
F head is used in some small engines and provides reasonably good airflow through the cylinder. This system is used when space is restricted in a compact engine design but fairly high output is needed.

T head is used in some stationary engines where space is not a problem. These engines tend to be quite wide at the top. Airflow is fairly good through the combustion chamber and the valve operating system is very reliable. This engine has one camshaft for the exhaust valves and one for the intake valves.

Cooling System Classification

Engines are sometimes classified according to the type of cooling system is uses. In many cases it is safe to assume that highway vehicles will be equipped with a liquid cooled engine and small recreational vehicles are powered by an air cooled engine. Diagrams 4.3 & 4.4 will show you

DIAGRAM 4.2: Valve Arrangements



two types of engine cooling systems.

Moving Engine Parts

Being able to understand the function of the main moving parts in the engine will make learning the operation of the engine easier. This information is also very useful for diagnosing engine problems. In this section, you will review the names and functions of the main moving parts in the internal combustion engine and be able to show the relationship between the different types of parts.

Moving Engine Parts and Their Functions

The moving parts in the internal combustion engine can be put into two groups. These are reciprocating parts and rotating parts. Reciprocating parts move back and forth. Rotating parts spin on an axis. The mechanical function of the engine depends on the conversion of reciprocating motion into a rotating motion. **Diagram 4.5** shows you a picture of various engine parts.

DIAGRAM 4.3: Air Cooled Engine

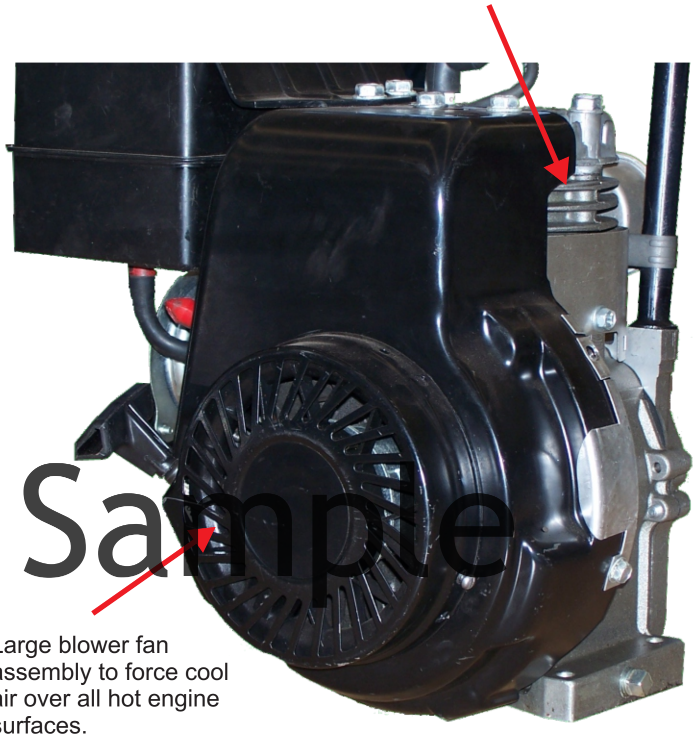


DIAGRAM 4.4: Liquid Cooled Engine

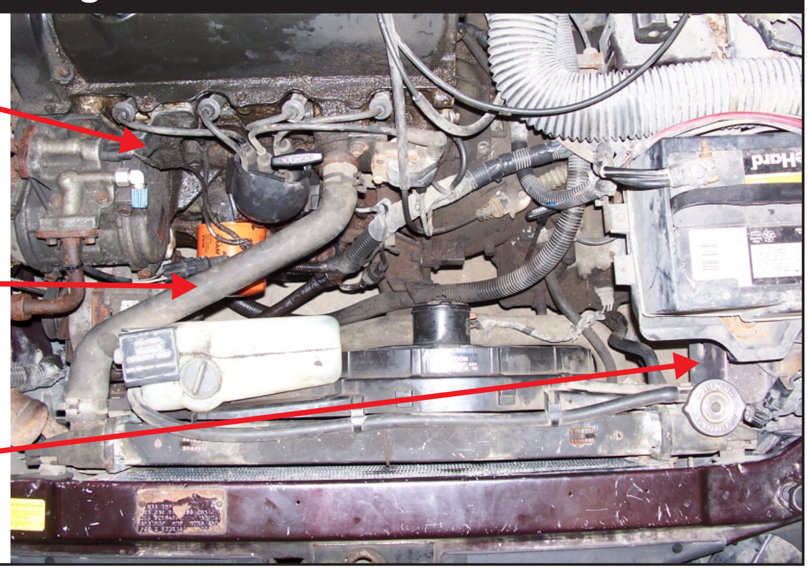
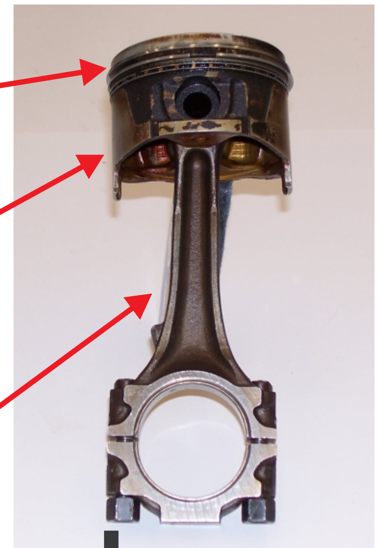


DIAGRAM 4.5: Moving Engine Parts

Piston Rings

Piston rings are located in grooves at the top of the piston to seal against pressure leakage past the piston and into the crankcase.



Piston

The piston and connecting rod are reciprocating parts. The piston is fitted into the cylinder bore and is the first part to receive the push of the burning and expanding gases in the cylinder.

Connecting Rod

The connecting rod attaches the piston to the crankpin on the crankshaft. The top end is attached to the piston by a strong piston pin (wrist pin). The bottom end is attached to the crankpin by a split bearing and bearing cap.

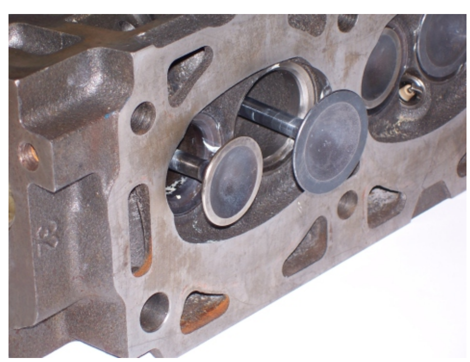
Camshaft

The camshaft is a rotating part. The camshaft is linked to the crankshaft by a chain, gears or a special cogged belt. When the proper time occurs, the camshaft will cause a valve to be opened in the proper sequence for engine operation. The camshaft converts rotary motion into the reciprocating motion needed by the valves.

Crankshaft

The crankshaft is a rotating part. The crankshaft is sometimes made of forged steel, but is usually cast. It is supported in the cylinder block by split plain bearings called main bearings. The crankshaft converts the reciprocating motion of the piston into rotary motion by the use of offset cranks called throws.

Valves



Valves are reciprocating parts. They are used to open and close a port in the cylinder head or block and each cylinder must have an intake and exhaust valve. The intake valve usually has a larger head than the exhaust valve and it allows air and fuel to enter the cylinder at the correct time. The exhaust valve allows the burnt air and fuel to leave the cylinder at the correct time.

Four Stroke Cycle

A good knowledge of the four stroke cycle is the main point of understanding the operation of the internal combustion engine and this information can be used in making accurate assessments and repairs to engine problems. You will learn the operation of the four stroke cycle and how the stationary and moving parts work together to produce an efficient and environmentally friendly engine.

Requirements for Engine Operation

In order to have the engine run, we must meet four requirements:

1. Supply the engine with air and fuel.

2. Prepare the air/fuel mixture for combustion.

3. Ignite the air/fuel mixture at the correct time.

4. Get rid of the burnt gases.

These four operations are known as four strokes. The strokes are called the Intake Stroke, Compression Stroke, Power Stroke and Exhaust Stroke.

Engine Valve Operation

In order to accomplish these four strokes we must open and close openings called ports at the correct time. These ports are located near the top of the cylinder. The Intake Valve controls when the air/fuel enters the cylinder. The Exhaust Valve controls when the burnt gases leave the cylinder.

Let's review each stroke with a little more detail. **Diagram 4.6** shows you diagrams of the four strokes.

Putting It All Together

At the end of the FOUR STROKE CYCLE the crankshaft has completed two complete revolutions. Since the piston is at TDC at the end of the four strokes the cycle will repeat over and over again until the engine runs out of fuel or the operator switches off the ignition system.

Remember!

A. Each stroke takes 1/2 of a revolution (180º) of the crankshaft to complete.

B. Four strokes take 2 revolutions (720º) of the crankshaft to complete.

C. Each valve must open one time only during the four strokes so the camshaft must turn at one half the speed of the crankshaft.

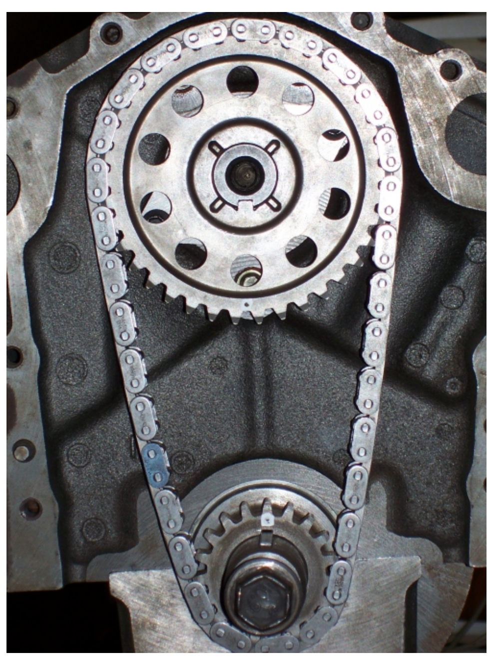


Photo 1.1: Timing Gear

This photo shows the relationship between the crankshaft sprocket (bottom) to the camshaft sprocket (top). The crankshaft turns twice to turn the camshaft once.

Page Notes

- Four Stroke Cycle
- Requirements of Engine Operation
- Engine Valve Operation
- Putting It All Together Summary of the Four Stroke Cycle

DIAGRAM 4.6: The Four Stroke Cycle

Glossary

- **TDC** - Top Dead Centre is the highest point of travel the piston will get to inside the cylinder.
- **BDC** - Bottom Dead Centre is the lowest point of travel the piston will get to inside the cylinder.

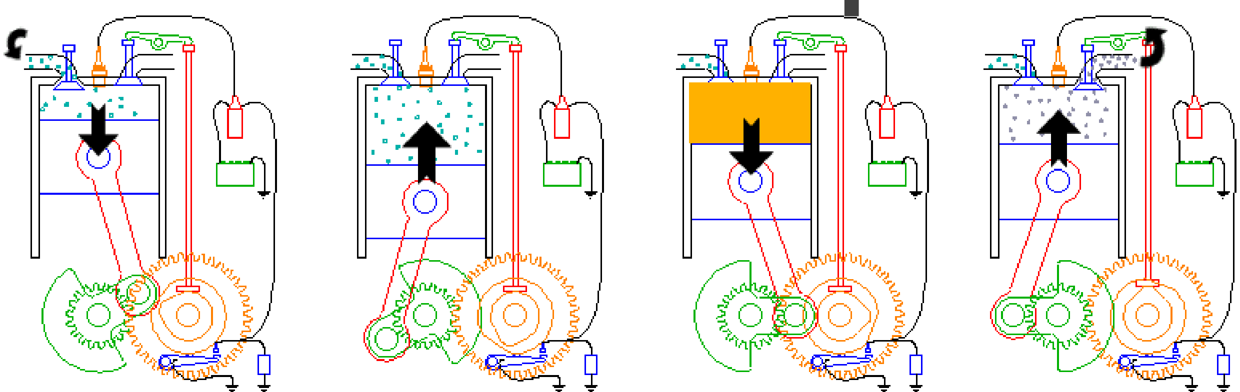
Intake Stroke

- At the start of the intake stroke, the intake valve is opened.
- The piston travels downward from TDC to BDC. This creates a partial vacuum in the cylinder.
- Atmospheric pressure forces air through the carburetor to pick up some fuel. This air/fuel mixture enters the cylinder past the open intake valve and through the open intake port.
- The exhaust valve stays closed during this operation.
- It takes the crankshaft half a revolution (180º) to complete this operation.

Compression Stroke

- Now, the intake valve closes the intake port and the piston moves upward from BDC to TDC.
- The mixture of air and fuel in the cylinder is compressed. The air and fuel are mixed together very well and heated up during this stroke.
- Both valves remain closed during this stroke.
- By now the crankshaft has completed one complete revolution (360º) and the piston is back at TDC.

Intake Stroke | **Compression Stroke** | **Power Stroke** | **Exhaust Stroke**



Power Stroke

- The highly compressed and heated mixture in the cylinder is now ready to be ignited. This is done electrically by a sparkplug or, in the case of a diesel engine, by the high temperature of the compressed air into which fuel is sprayed.
- Combustion is immediate. The mixture, as it burns, expands rapidly and greatly increases the pressure inside the cylinder. The high pressure forces the piston downward from TDC to BDC.
- At this point the crankshaft has completed one and one half revolutions (540º) from the cycle starting point and the piston ends up at BDC.

Exhaust Stroke

- The cylinder is now full of burnt gases that must be removed.
- The exhaust valve opens the exhaust port and the piston moves upward from BDC to TDC. This forces the exhaust gases out of the cylinder.
- During this stroke the intake valve is closed.
- The exhaust stroke is the last one in the Four Stroke Cycle. At the end of the Four Stroke Cycle the crankshaft has completed two complete revolutions (720º).

Keeping the Engine Running Smoothly

Did you notice in **Diagram 4.6** that there is only one stroke that actually supplies power to the engine through the two revolutions of the crankshaft? This situation will cause the engine to supply power in surges which is unacceptable. Attaching a heavy flywheel to the crankshaft will reduce this problem. The **momentum** of the flywheel carries the engine crankshaft smoothly from one power stroke to the next.

Engine Valve Timing

A clear understanding of valve timing will enable the student to perform troubleshooting and engine improvements in the future. In this section, will learn the actual valve timing method used in an internal combustion engine and be able to understand how engine performance may be improved with simple valve timing changes.

When learning about the four stroke cycle in the previous section, you were told that the valves closed and opened either at TDC or BDC and the cycle uses 720º (2 turns) of crankshaft rotation.

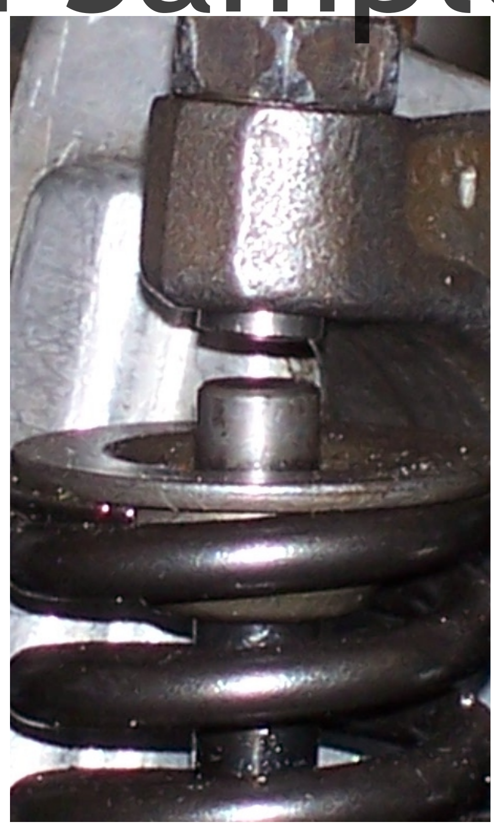
In real life the valves begin to open before and close after TDC or BDC is reached and uses more crankshaft degrees. The valve timing is set up this way to provide the engine with more power by allowing air and fuel to enter the cylinder efficiently and by removing all traces of exhaust.

Valve timing is linked directly to the position of the piston and crankshaft. When talking about valve opening and closing we relate the valve position to crankshaft degrees. Keep in mind that the figures given on the next screen are only for the purpose of explaining valve timing. Every model of engine has different timing specifications depending on what it will be used for.

Putting It All Together

Because of improved valve timing we have changed the **actual length** of the effective cycle from 720º to 730º as shown in this example. Engine designers have tried, over the last century, many different ways to increase engine output. Changes in valve timing were discovered at the turn of the century as a way to increase power and we still use this method, especially in performance engines.

A **performance camshaft** is designed to increase the actual length of the cycle, hold



Know the Language

momentum

Momentum is the energy stored in a moving object. In this case, momentum is stored in the spinning flywheel. Once the flywheel is spinning it will want to continue to spin and will carry the attached crankshaft with it.

actual length

The actual length of the four stroke cycle is controlled more by the start and finish of the strokes than it is by piston/crankshaft position. The start and finish of a stroke is determined by when a particular valve leaves its seat until it returns to it. In other words, the exhaust stroke actually lasts from the instant the exhaust valve starts to open until it is completely closed. The position of the piston is secondary. A longer stroke will produce more engine output up to a certain point.

performance camshaft

A performance camshft will change various aspects of engine valve timing. Some "cams" are designed strictly for racing, while others work best for performance street driving conditions. Seek expert advice when deciding on the camshft you want to install. Some problems with changing the camshaft are poor idle quality, increased fuel consumption, breaking anti-pollution laws and voiding a new vehicle warranty agreement.

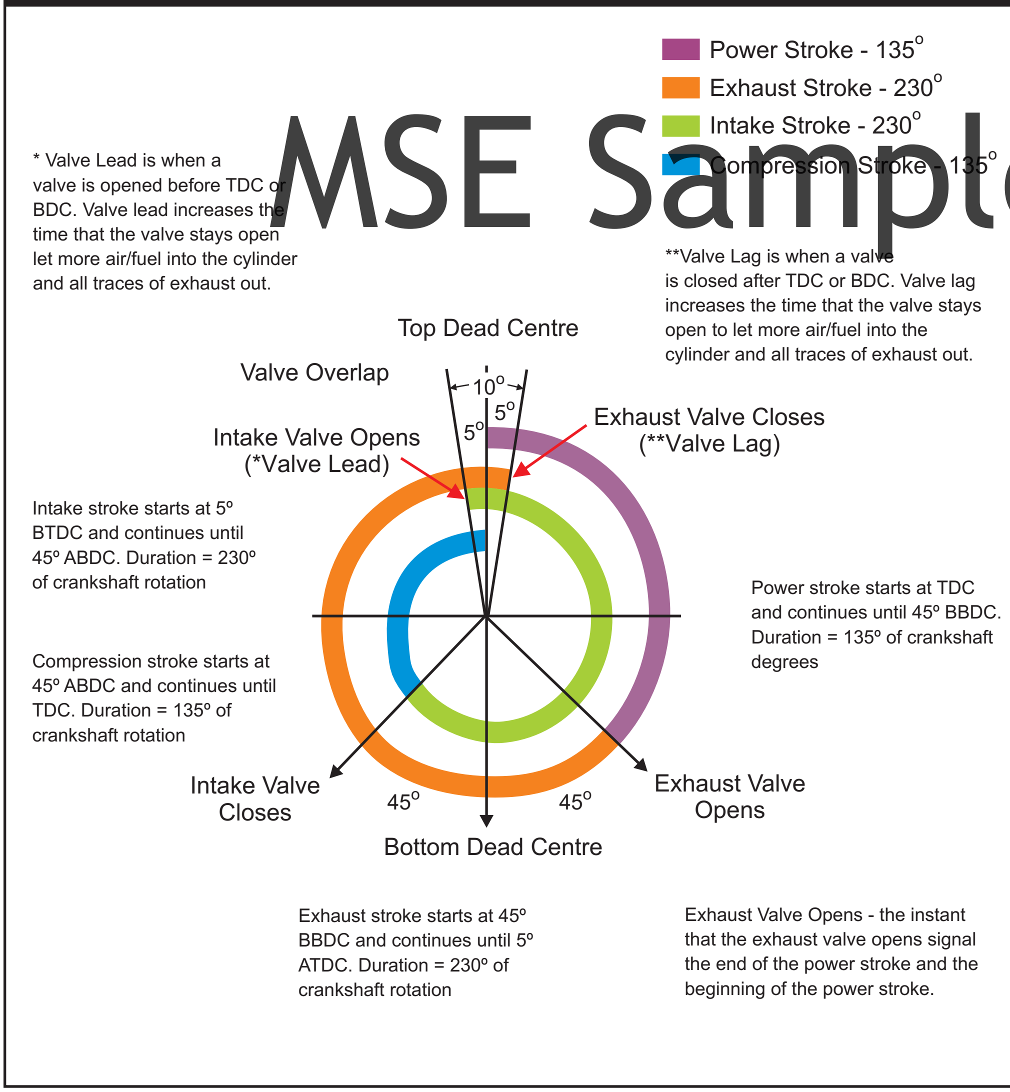
the **valves open longer** and also to open the ports wider by **lifting the valve** higher off its seat. The greater the amount of air and fuel that can be put into the cylinder during the intake stroke, the higher the volumetric efficiency of the engine. An engine with good **volumetric efficiency** will produce more horsepower.

Can you think of any more ways to increase the volumetric efficiency of an engine by using the following items?

a) larger valves
b) supercharger
c) turbocharger
d) intake manifolds
e) exhaust system modifications, etc.

Visit an engine performance shop or talk to someone who does performance work. Find out at least five different ways to increase the volumetric efficiency of an engine. Explain on page two of your worksheet how each improvement will work toward this end.

DIAGRAM 4.7: Valve Timing Chart



Page Notes
- Engine Valve Timing
- Valve Timing Chart

Know the Language

valves open longer

A performance camshaft will, in most cases, open the valves for a longer period of time (more degrees of crankshaft rotation). This is done to increase the amount of air/fuel that can enter the cylinder and to allow the exhaust to leave the cylinder faster. The term given to how long the valve is held open is "Valve Duration". It is given in degrees of camshaft rotation or crankshaft rotation.

lifting the valve

Lifting the valve higher off its seat will allow more air/fuel to enter the cylinder and make it easier for quick exhaust removal. Most performance camshafts will lift the valve more and for a longer period of time that a stock camshaft. The term given to the amount a valve is lifted off its seat is "Valve Lift".

Volumetric efficiency

Compares how much air/fuel can be placed in an engine cylinder when the engine is stopped with the piston at BDC to how much air/fuel is placed in an engine cylinder during the intake stroke when the engine is running. The closer the two situations come to a match, the better the engine will perform. Volumetric efficiency is sometimes called breathing efficiency.

Engine Measurements And Performance

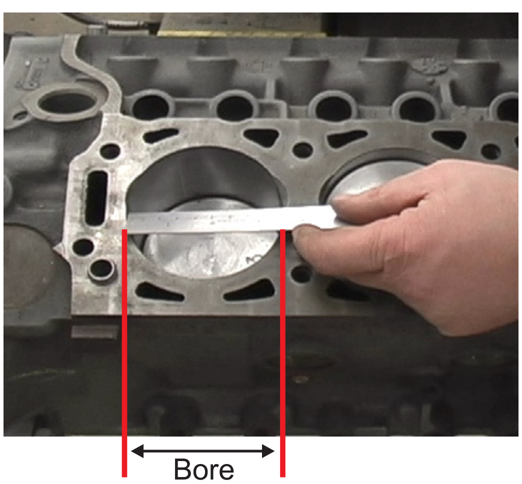
In order to carry on an intelligent conversation regarding an engine, a good knowledge of basic terminology is needed. This will be useful in understanding what a technician is telling you when engine repairs are needed. Also, knowing this terminology will help you understand sales literature and track reports. This section will teach you standard terminology used in the discussion of engine parts and power related measurements. You will also learn how to calculate Total Volume, Piston Displacement and Compression Ratio.

Definitions

Here are some definitions of common terms that are important to know in order for everyone to understand what is being discussed.

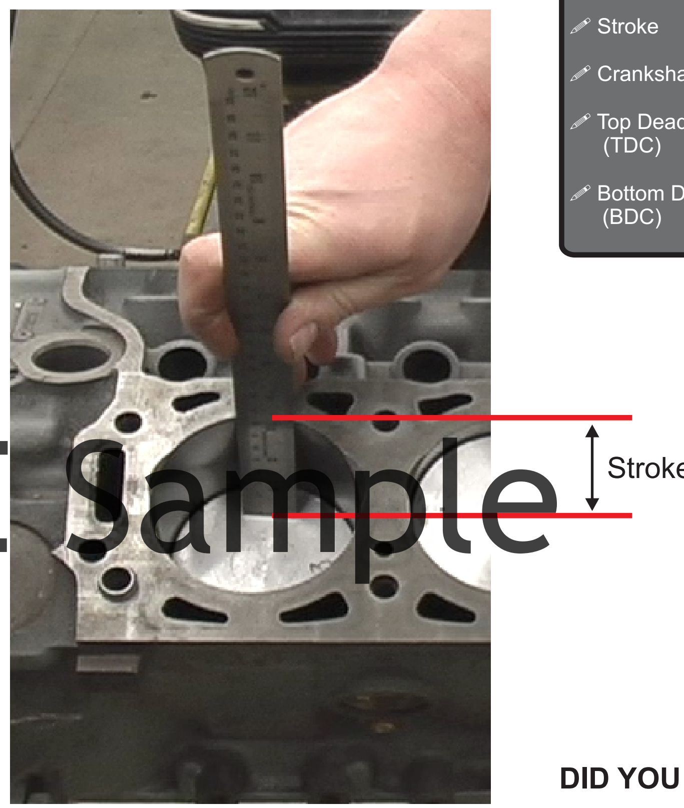
<u>Bore</u>

This is the inside diameter of the cylinder and is measured in millimetres or inches.



<u>Stroke</u>

This is the distance in millimetres or inches travelled by the piston in its movement from TDC to BDC. Two strokes of the piston is equal to one turn of the crankshaft.



<u>Crankshaft Throw</u>

This is the distance from the center of the crankshaft main bearing journal to the center of the crankpin. The stroke of the piston is equal to twice the length of the throw. It is measured in millimetres or inches.

<u>Top Dead Centre (TDC)</u>

This is the farthest point of upward travel of the piston in the cylinder.

<u>Bottom Dead Centre (BDC)</u>

This is the lowest point of downward travel of the piston in the cylinder.

Page Notes

- Engine Measurements and Performance
- Definitions
- Bore
- Stroke
- Crankshaft Throw
- Top Dead Centre (TDC)
- Bottom Dead Centre (BDC)

DID YOU KNOW?

An engine that has a bore and stroke that are identical in size is often called "square". So if the bore is 90mm and the stroke is 90mm, the engine is square. When the stroke is larger than the bore, the engine is referred to as "under square". When the bore is bigger than the stroke the engine is "over square".

RPM (Revolutions Per Minute)

This is the unit of measurement used to determine the speed of a rotating part. If an engine is said to be turning at 2000 RPM, it means that the crankshaft will make 2000 complete revolutions in one minute.

Engine Performance

You often see the terms "Horsepower" and "Torque" referred to in vehicle sales literature and service manual specification charts.

Power

Power (Horsepower, kW) is the rate at which the engine will do work. The horsepower produced by an engine changes according to the engine speed. All engines have a peak horsepower point that occurs at a pre-determined engine speed. This speed is usually the point of highest operating efficiency.

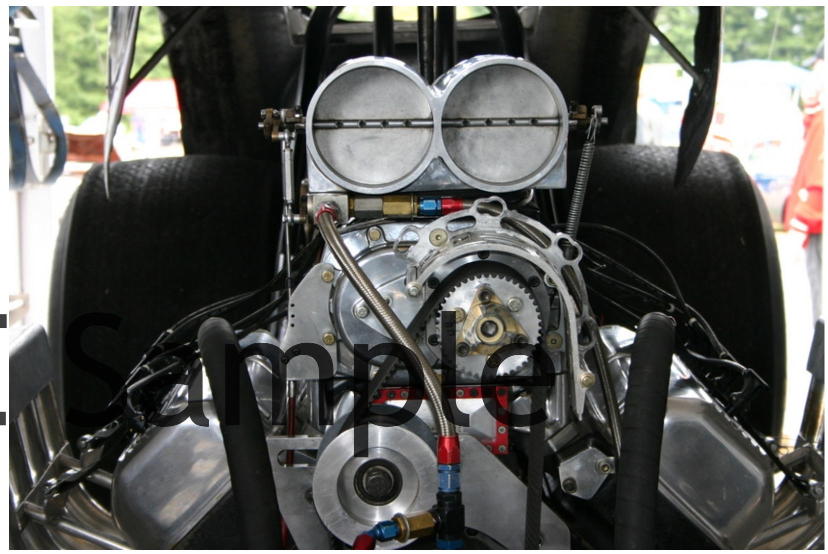
Advertised horsepower (net horsepower) is greatly reduced by the time it reaches the wheels due to frictional losses and accessory loads. For example a 250 net HP engine would only have approximately 150 HP available at the drive wheels. High horsepower engines generally produce less torque because they have a short stroke. A high horsepower vehicle will be fast but cannot pull a large amount of weight.

Torque

Torque is the measurement of turning effort put out by the engine. Torque is usually measured in N.m (Newton metres) of lbs./ft. (pounds/feet). Engine torque is a more accurate indicator of the possible performance of an engine. High torque engines generally have lower horsepower because they have a longer stroke. High torque engines produce their rated torque at fairly low speeds. A high torque vehicle is not very fast but will pull a lot of weight.

Page Notes

- RPM
- Engine Performance
- Power
- Torque



These dragster engines are designed for maximum horsepower and torque

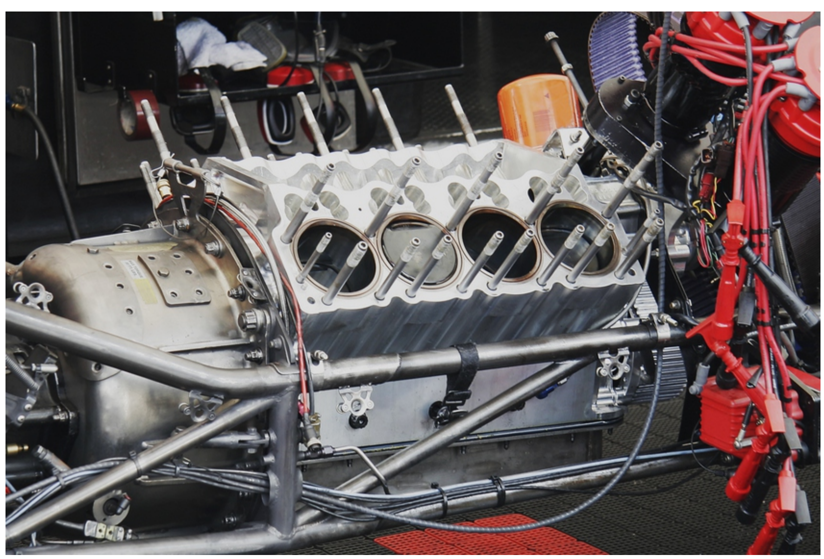
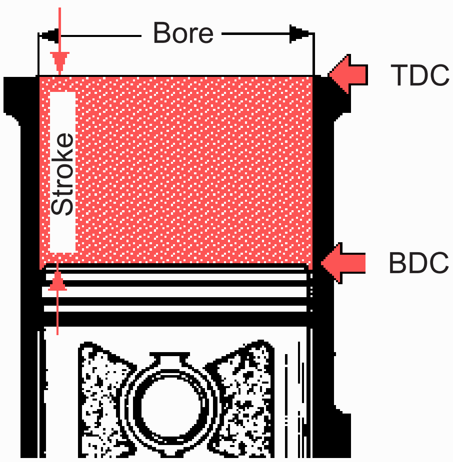
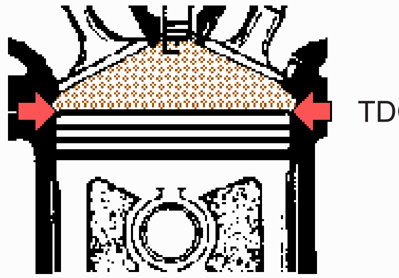
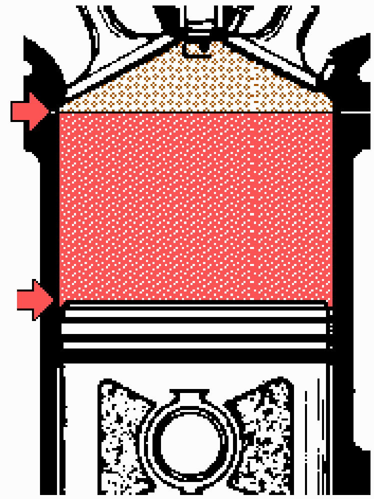


DIAGRAM 4.8: Engine Measurements







Total Volume (TV)

Total volume is the total volume in the cylinder above the piston when the piston is at BDC. Total volume is equal to piston displacement + clearance volume. TV = PD + CV

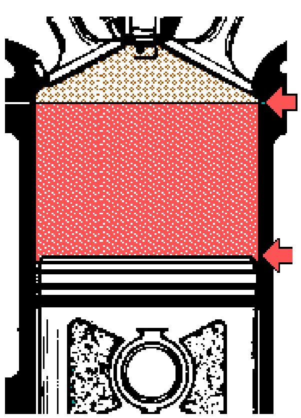
Clearance Volume (CV)

Clearance volume is the volume of the combustion chamber above the piston when the piston is at TDC. It is measured in cubic centimetres (cc) or cubic inches (ci). Because the shape of the combustion chamber is irregular it is hard to measure. The clearance volume is calculated by carefully measuring the amount of water it takes to fill it up. In most situations the CV is given to you to make other calculations easier.

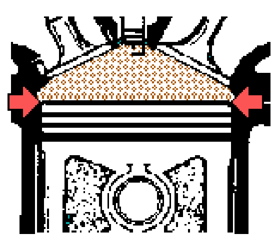
Piston Displacement (PD)

Piston displacement for one cylinder refers to the volume that the piston displaces as it travels from BDC to TDC. It is measured in cubic centimetres (cc) or cubic inches (ci). Piston displacement for one cylinder is calculated using this formula: $PD = \pi \times r^2 \times \text{stroke}$. To get the displacement for a mult-cylinder engine just multiply the PD × the number of cylinders.

DIAGRAM 4.9: Compression Ratio



This cylinder is completely full of the air/fuel mixture



The air/fuel mixture has now been compressed

Compression Ratio (CR)

Compression ratio represents how much a completely full cylinder is compressed when the piston moves from BDC to TDC. It is the ratio of the TV of a cylinder to the CV.

Compression ratio is calculated using this formula: $CR = TV \div CV$.

It is expressed in the form of a ratio such as 10:1